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Study of Comparison of Use of “Ommaya Reservoir Parenchymal Catheter Assembly vs Open Parenchymal Catheter” for Minimally Invasive Clot Lysis and Evacuation of Hypertensive Supratentorial Intracerebral Bleed

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Abstract: ***Background:*** Spontaneous intracerebral hemorrhage (ICH) is a catastrophic neurological illness with high morbidity and mortality. Minimally invasive clot lysis therapy, such as the use of an Ommaya reservoir-parenchymal catheter assembly and an open parenchymal catheter, holds promise over conventional medical and surgical treatment. The two methods are compared in this study regarding hematoma reduction, neurological improvement, and procedural safety. ***Methods:*** This prospective, observational, comparative study was conducted at Sahyadri Specialty Hospital, Pune, from December 2018 to June 2020. A total of 82 patients with spontaneous supratentorial ICH were included, with 41 patients in each treatment group. Patients underwent minimally invasive clot lysis with urokinase, and outcomes were assessed using Glasgow Coma Scale (GCS), National Institute of Health Stroke Severity (NIHSS) score, hematoma volume reduction, and complication rates. Statistical analysis was performed using SPSS software. ***Results:*** Both groups demonstrated significant reduction of hematoma, with more reduction at 24 hours in the Ommaya group. One-month follow-up revealed significantly improved GCS and NIHSS scores in the Ommaya group compared to the catheter group. Meningitis was seen in six patients in the catheter group and one patient in the Ommaya group. Hematoma expansion or rebleeding was not seen in either group. ***Conclusion:*** Minimally invasive clot lysis via the Ommaya reservoir is an effective and safe method, providing improved neurological recovery and fewer complications than open parenchymal catheter. Large multicenter trials are required to validate these results.

Keywords: Intracerebral hemorrhage, minimally invasive surgery, Ommaya reservoir, parenchymal catheter, urokinase, hematoma evacuation.

INTRODUCTION

Spontaneous intracerebral hemorrhage (ICH) is a common and lethal neurological condition with disastrous outcomes. It strikes in an earlier age group than the other stroke syndromes and carries the highest case fatality of all the stroke subtypes [1]. Nonlesional spontaneous ICH or primary ICH is

intraparenchymal hemorrhage in the absence of a detectable underlying structural lesion such as trauma, tumor, aneurysm, vascular malformation, or arteriovenous fistula. Spontaneous ICH has an annual incidence of 10 to 30 cases per 100,000 population [2]. Although it is responsible for only 10–15% of all strokes, it is associated with an overwhelmingly high mortality of 20% to 70% in different reports [3,4,5]. The overall 30-day mortality is high at approximately 50% [6,7]. Of the survivors, 75% become functionally dependent, with only approximately 25% regaining functional independence at six months [3].

The etiology of spontaneous ICH is different with age. In young individuals, the frequent causes are drug abuse (e.g., cocaine, amphetamines, and alcohol), aneurysms, and vascular malformations. In elderly individuals, the frequent causes are hypertension, vasculopathy, tumors (metastatic and primary), coagulopathies (due to anticoagulants such as warfarin, heparin, aspirin, and fibrinolytic therapy). Leukemia is an important cause of ICH in children. Hypertensive ICH is the most frequent type and occurs in approximately 80% of cases. The most frequent locations of hypertensive ICH are basal ganglia (50%), lobar regions (20–50%), thalamus (10–15%), pons (5–12%), and cerebellum (1–5%) [4]. The clinical presentation is highly variable and can range from minimal local neurological findings to coma and death. Small hemorrhages can present as ischemic stroke with focal deficit but without considerable impairment of consciousness, headache, or nausea.

In the past, ICH was thought to be a monophasic phenomenon [8]. Yet, recent studies have shown that early hematoma expansion is a frequent phenomenon in ICH patients [9,10,11]. The development of mass effect secondary to edema follows a biphasic pattern: early (within 2–5 days) and late (within 2–3 weeks). Several studies have been performed to identify an optimal treatment plan for ICH. Surgery has the theoretical benefit of decreasing hematoma volume, with evidence that removal of the clot may reduce neuronal injury by reversing local ischemia and removing toxic substances. But direct open surgical evacuation has disadvantages, such as patient instability, further brain injury, and a higher risk of postoperative rebleeding. Surgical results are heterogeneous, with some patients experiencing benefits but not all. Long-term morbidity and mortality associated with surgical treatment are similar to those of medical treatment. Minimally invasive ICH evacuation procedures have been in the spotlight due to the potential for decreasing the volume of hematoma without an accompanying increase in surgical morbidity. The rationale for these procedures is to relieve mass effect and allow quicker recovery. This study will ascertain whether clot lysis and evacuation using the Ommaya reservoir is equal in outcome to the open parenchymal catheter system but potentially at less risk for infection. An earlier study at a single institution determined the efficacy of the open parenchymal catheter system for clot lysis and evacuation. This study is a follow-up to that research, with emphasis placed on reducing the risk of infection through a closed system approach. The study will compare clot reduction, outcome, complications, and rate of infection for the two procedures. The result of this study can potentially determine the feasibility, safety, and worth of the Ommaya reservoir in minimally invasive clot evacuation.

METHODS

Study Region and Population

This study was conducted at Sahyadri Specialty Hospital, Pune, a referral tertiary care hospital with advanced neurosurgical and critical care services. Study population included patients admitted with spontaneous nonlesional intracerebral hemorrhage (ICH) according to imaging diagnosis. Patients satisfying the pre-decided inclusion and exclusion criteria were enrolled in the study.

Study Design and Sample Size

The research design was comparative, observational, and prospective. The patients were recruited between December 2018 and June 2020. The sample size was computed from the effect sizes of previous studies by the use of a formula that entailed standard normal variates, standard deviation, and mean difference in clot size. The minimum sample size to be computed was 82 patients, with 41 patients assigned to each of the treatment groups. Purposive sampling was used to sample the participants.

Inclusion and Exclusion Criteria

Patients aged 18 to 65 years, either sex, with a Glasgow Coma Scale (GCS) score between more than 5 and less than 14 on admission, and a National Institute of Health Stroke Severity (NIHSS) score of 6

or greater were randomized. Imaging evidence of spontaneous supratentorial ICH, clot volume of 30 cc or greater, and less than 72 hours' ictus time were mandatory for entry. An aneurysmal, tumor, traumatic, or angiographically diagnosed vascular malformation-induced hemorrhage was an exclusion criterion. Other exclusion criteria were large intracerebral hemorrhage with intraventricular extension, irreversible brainstem dysfunction, severe coagulopathies, allergy to Urokinase, and any other condition deemed to be of a significant risk to the patient if the investigational therapy was initiated.

Patient Selection and Preoperative Evaluation

Patients satisfying the inclusion criteria were subjected to a detailed clinical examination, history, past history, and history of drugs. Spontaneous ICH was diagnosed on the basis of clinical presentation of acute onset neurological deficit and was confirmed on brain CT scan. Informed consent of the patient or assent from relatives was obtained. Baseline neurological status on admission was assessed with the help of GCS and NIHSS. Hematoma location and size were documented on imaging. Patients were classified based on the "Zone Concept," which grades cases into surgical, catheter-based, or conservative management based on clot size, mass effect, and neurological status.

Preoperative Preparation

The patients were all transferred to the Neuro-Intensive Care Unit (NICU) and vital functions were stabilized. Endotracheal intubation was performed if airway compromise was observed. Monitoring and management of hypertension was performed to reduce the risk of hematoma expansion. Antiepileptic medication was administered if required, and osmotic therapy with mannitol was performed in cases of increased mass effect. Coagulation tests and hematological investigation were performed, and contrast-enhanced CT or CT angiography was performed in cases of suspected secondary causes of hemorrhage.

Surgical Intervention and Catheter Insertion

After initial stabilization and radiologic evaluation, patients were brought to the operating room. Brainlab navigation system was used to enable precise catheter placement. Preoperative CT scanning with Brainlab guidance was used to estimate hematoma volume and target point. An 8 mm perforator was used to create the bur hole, and a blunt brain needle was inserted using Brainlab navigation guidance. One catheter was placed into the hematoma cavity and fixed in place. In the Ommaya group, the catheter was attached to an Ommaya reservoir, but in the open catheter group, the catheter was left open to spontaneous drainage.

Urokinase Instillation and Postoperative Monitoring

Following catheter placement, the primary hematoma was allowed to drain spontaneously. Urokinase was infused into the clot every 6 to 8 hours in a dose of 50,000 units in strict aseptic conditions. Following each injection, the catheter was irrigated with 2 cc sterile saline and clamped for 60 minutes before being opened for drainage. Treatment was repeated for a total of 72 hours or until there was significant reduction of clot.

Postoperatively, the patients were kept under close observation in the NICU for neurological examination, vital signs, and complications such as rebleeding, infection, and malfunction of the catheter. GCS, NIHSS scores, and pupillary function were checked at regular intervals. Follow-up CT scan was performed 24 hours after the procedure to document the reduction in clot and to ensure catheter position.

Outcome Measures and Statistical Analysis

The primary outcome measures were the reduction of hematoma volume at 24 hours, mean reduction of hematoma at treatment completion, NIHSS and GCS scores at one month, and procedural complications such as mortality, rebleeding, meningitis, bacterial ventriculitis, and cerebritis. Statistical Package for Social Sciences (SPSS version 16.0, IBM Corporation, USA) was employed to carry out the analysis. Categorical variables were reported as percentages, while continuous variables were reported as means and standard deviations. Chi-square or Fisher's exact test was employed to compare categorical data, while paired t-tests and Wilcoxon's signed rank test were employed for intra-group comparisons of continuous and categorical variables, respectively. Normality

assumptions were tested before carrying out statistical tests, and a p-value of <0.05 was considered statistically significant.

RESULTS

This research compared Ommaya reservoir insertion and parenchymal catheter insertion in 82 patients (41 in each group) on the basis of demographic characteristics, clinical outcomes, reduction of clot volume, and complications.

Gender and Age Distribution

Both groups were comparable in gender distribution (p = 0.659) and age distribution (p = 0.964) with no significant difference. The mean age was 53.95 ± 12.35 years in the Ommaya group and 54.07 ± 12.19 years in the catheter group (Table 1).

Table 1: Gender and Age Distribution of Cases

Characteristic	Ommaya Group (n=41)	Catheter Group (n=41)	p-value
Male	22 (53.7%)	20 (48.8%)	0.659
Female	19 (46.3%)	21 (51.2%)	
Mean Age (Years)	53.95 ± 12.35	54.07 ± 12.19	0.964

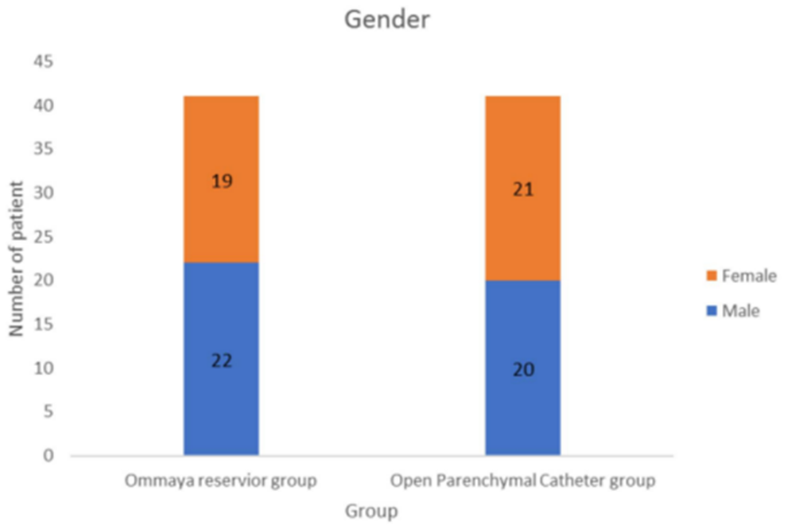

Figure 1: The gender distribution of cases studied (n = 41 per group)

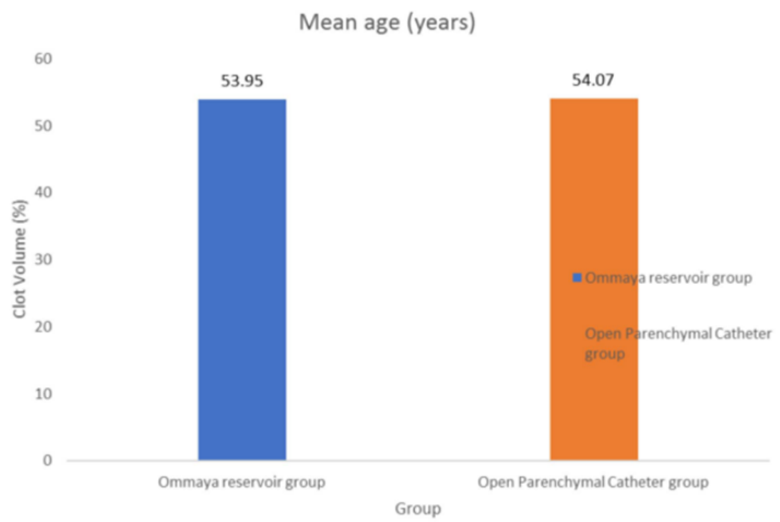

FIgure 2: The age distribution of cases studied (n = 41 per group)

Neurological Recovery (GCS & NIHSS Scores)

- Glasgow Coma Score (GCS) showed marked improvement in the Ommaya group after surgery (p = 0.026) (Table 2).
- NIHSS score further exhibited postoperative improvement in the Ommaya group as well (p = 0.033).

Table 2: Comparison of GCS and NIHSS Scores

Score Type	Ommaya Group (Mean ± SD)	Catheter Group (Mean ± SD)	p-value
Pre-Op GCS	8.12 ± 2.61	8.20 ± 2.59	0.899
Post-Op GCS (1 month)	12.68 ± 2.70	11.51 ± 1.90	0.026
Pre-Op NIHSS	16.54 ± 3.85	16.59 ± 3.83	0.954
Post-Op NIHSS (1 month)	9.73 ± 2.88	12.63 ± 5.36	0.033

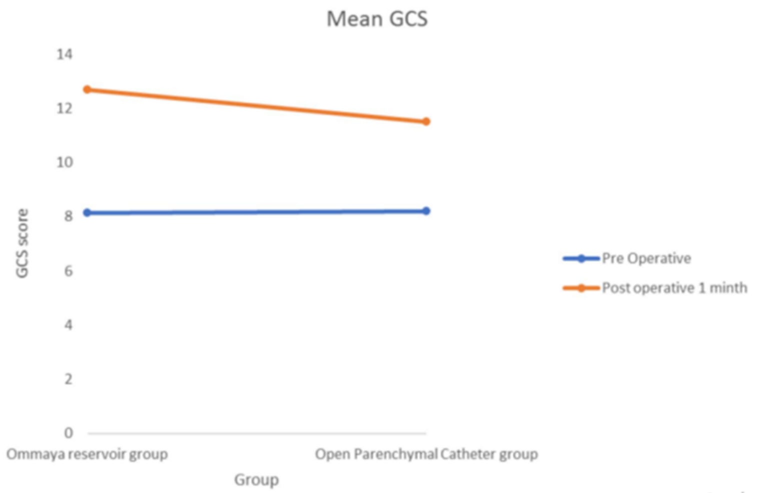

Figure 3: The distribution of Glasgow coma score among the cases studied (n = 41 per group)

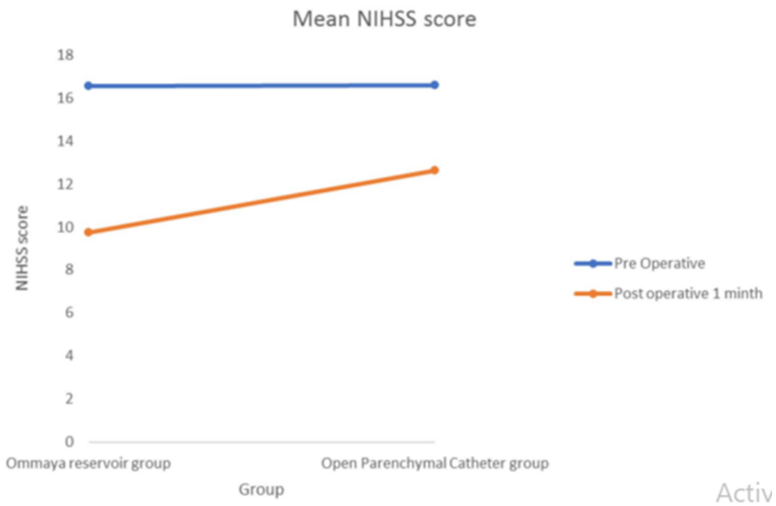

Figure 4: The distribution of National Institutes of Health Stroke Scale (NIHSS) on admission among the cases studied (n = 41 per group)

Clot Volume Reduction

- Preemptive early reduction of the clot at 24 hours was considerably greater in the Ommaya group (p = 0.006), whereas global clot reduction was equivalent (p = 0.155) (Table 3).
- The incidence of meningitis was much greater in the catheter group (p = 0.048).

Table 3: Clot Volume Reduction and Complications

Parameter	Ommaya Group (Mean ± SD)	Catheter Group (Mean ± SD)	p-value
Initial Clot Volume (cc)	68.60 ± 23.29	68.92 ± 23.53	0.988
Clot Reduction at 24 hrs (%)	45.24 ± 11.85	37.39 ± 13.22	0.006

Final Clot Reduction (%)	70.43 ± 17.87	64.75 ± 19.37	0.155
Meningitis Cases (n, %)	1 (2.4%)	6 (14.6%)	0.048

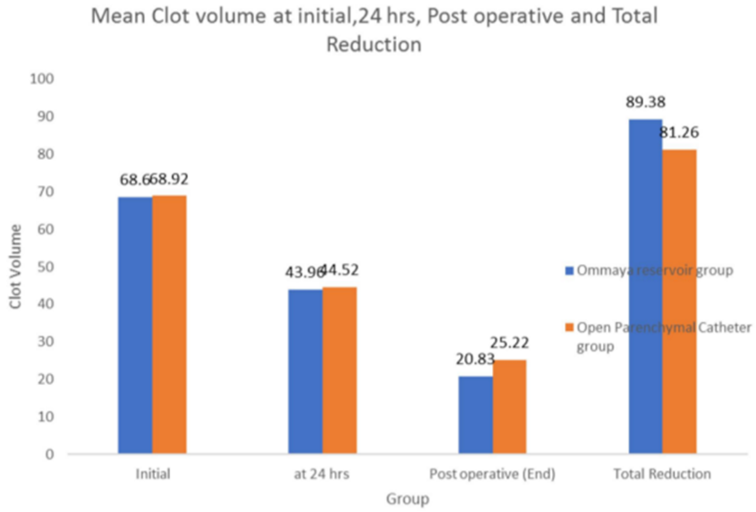

Figure 5: The distribution of mean clot volume on admission, 24h-Hrs post-treatment and at the end of the treatment (n = 41 per group)

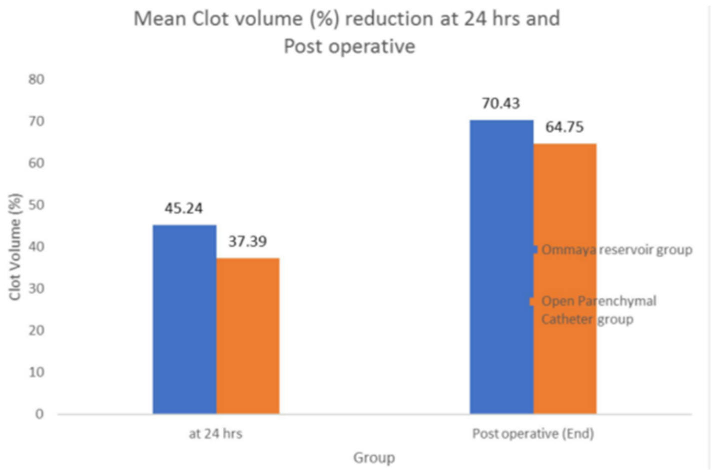

Figure 6: The distribution of % clot volume reduction, at 24h-Hrs post-treatment and at the end of the treatment (n = 41 per group)

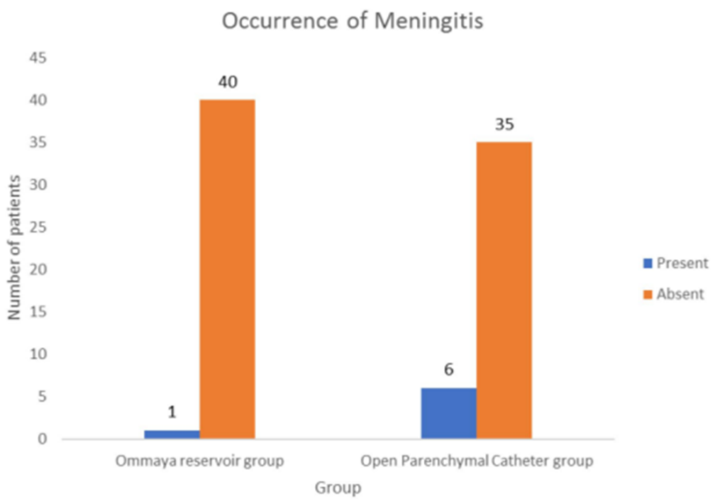

Figure 7: The distribution of meningitis among the studied group (n = 41 per group)

The Ommaya reservoir group showed improved postoperative recovery (GCS & NIHSS), more early clot reduction, and reduced risk of meningitis, thus emerging as a preferred choice in selected patients.

DISCUSSION

Spontaneous intracerebral hemorrhage (ICH) is a catastrophic illness with severe morbidity and mortality, frequently resulting in long-term neurological disability and impairment [3]. Mortality has been reported between 20% and 70%, with worse initial neurological condition and larger hematoma being independent predictors of poor outcome [3,4,5]. Heterogeneity of hemorrhage location, size, and clinical presentation makes it difficult to standardize treatment protocols. Historically, research has shown that small hematomas (<35 mL) have a favorable prognosis no matter what intervention is undertaken, whereas large hematomas (>200 mL) have poor outcomes and high mortality [12]. Optimal management for hematomas of a middle size, however, is unclear with an understanding that no agreement exists regarding whether or not surgical management offers a marked advantage over medical management.

In this analysis, we compared the results of patients with spontaneous ICH treated with Ommaya reservoir insertion versus an open parenchymal catheter. Our data indicate that minimally invasive treatments can be beneficial in decreasing clot volume and enhancing neurological outcomes. As in earlier studies, increased age was related to a greater frequency of ICH, with those aged over 80 years being disproportionately impacted [9]. Nonetheless, among our study population, age had no significant effect on the clinical outcome in either group. Gender was also similar between groups, in keeping with epidemiological findings indicating a greater incidence of ICH in men, although no significant gender-related differences in outcome were observed [13-17].

Hypertension is the most frequent risk factor for spontaneous ICH, especially in deep brain structures [18]. Our research detected a high incidence of hypertension in both groups (78.04% within the Ommaya group and 73.17% within the catheter group), consistent with earlier studies that reported an incidence of 45%-50% of ICH patients [19,20]. Diabetes mellitus, which is another frequent vascular risk factor, was identified in 14.63% of patients within the Ommaya group and 19.51% within the catheter group. In addition, a high percentage of patients had a history of drug abuse, such as tobacco use, gutkha chewing, and alcohol use, which are known to be risk factors for ICH because they contribute to vascular pathophysiology [21,22].

Neurological status on admission is an important predictor of outcome in ICH. The majority of patients in this study presented with low Glasgow Coma Scale (GCS) scores at admission, with no difference between the groups. But by one month, the Ommaya group had very much improved neurological recovery, as reflected in better GCS and NIHSS scores. This implies that utilization of the Ommaya reservoir can help achieve improved hematoma resolution and neurological recovery compared to the open catheter placement. Earlier clot reduction has been shown to impact recovery, with larger hematomas (>30 mL) being linked with increased mortality and poorer functional outcome [2,6,23]. In the present study, the Ommaya group had significantly more clot volume reduction at 24 hours than the catheter group, yet final hematoma resolution at the completion of treatment was not different between groups. These results agree with earlier research proving that minimally invasive methods can produce large clot reduction [24].

There has been greater investigation into minimally invasive surgical methods in ICH management, with numerous studies reporting potential advantages over open surgery or medical therapy alone. The MISTIE trial showed notable reduction in clot and better functional outcome when compared with medical treatment alone [25]. Our data corroborate the above findings since the Ommaya group also experienced better clinical outcomes with reduced complication rates. While prior studies have reported a rebleed rate of approximately 5.6% with minimally invasive clot evacuation [25], we did not observe any cases of rebleeding or hematoma expansion in either group, indicating the safety of both techniques.

Complications associated with surgical intervention, particularly infection, remain a concern. In our research, meningitis was more prevalent in the catheter group (14.6%) than in the Ommaya group (2.4%), indicating that the closed profile of the Ommaya reservoir might decrease the risk of infection. Other studies have also found this, with decreased infection rates in connection with minimally

invasive procedures in comparison to open surgery [26]. The lower complication rate in the Ommaya group further supports its potential as a preferred approach in selected cases.

Functional recovery following ICH is heavily influenced by clot burden, initial neurological status, and the success of early clot evacuation. Our study found that patients with smaller hematomas (<60 mL) had significantly better outcomes at one month, irrespective of the surgical technique used. This result is in agreement with other research that hematoma size is a significant prognostic determinant [2,6]. The median catheter placement duration was also slightly longer among the Ommaya group (4 days) than among the catheter group (3 days), although this did not impact on clinical outcomes significantly.

Long-term mortality after ICH is high, with most series citing 30-day mortality of between 34% and 40% with medical therapy alone [27,28]. The STICH trial showed mortality at 36% in patients treated with early surgery versus 37% in those treated conservatively, indicating that open surgical intervention does not have a major survival benefit [29]. Conversely, minimally invasive surgical methods have been linked with reduced mortality, as evidenced in the MISTIE and ICSE trials [30]. Our research concurs with this trend, as we noted reduced mortality and better functional outcomes in patients who received the Ommaya reservoir compared to the catheter group.

In general, our results indicate that minimally invasive clot evacuation via an Ommaya reservoir is a safe and effective treatment alternative to open catheter drainage for spontaneous ICH. The Ommaya group had superior neurological recovery, higher early clot reduction, and reduced infection rates. These findings are consistent with current literature highlighting the benefits of minimally invasive therapy in appropriately selected patients. Although both procedures resulted in equal ultimate clot resolution, the Ommaya reservoir potentially provides better early functional benefit and fewer complications. More randomized controlled trials involving larger patient samples are required to validate these data and further modify treatment regimens for spontaneous ICH.

CONCLUSION

Minimally invasive clot lysis with the Ommaya reservoir-parenchymal catheter assembly and the open parenchymal catheter showed marked hematoma reduction in hypertensive supratentorial intracerebral hemorrhage patients. Although both therapy modalities were effective in reducing clot volume, the Ommaya group had statistically significant better outcomes of GCS and NIHSS scores at one month follow-up, as well as decreased complications in the form of meningitis. The research revealed that patients with lower NIHSS scores upon admission fared better, and neither group experienced an increase in hematoma size or rebleed. The results indicate that minimally invasive clot lysis via the Ommaya reservoir is a safe and effective option compared to open parenchymal catheter placement. Nonetheless, due to the single-center design of the study and the small sample size, additional large-scale, multicenter studies are needed to confirm these findings.

REFERENCES

1. Bamford, J., Sandercock, P., Dennis, M., Burn, J., & Warlow, C. (1990). A prospective study of acute cerebrovascular disease in the community: The Oxfordshire Community Stroke Project—1981-86. Incidence, case fatality rates, and overall outcome at one year of cerebral infarction, primary intracerebral, and subarachnoid haemorrhage. *Journal of Neurology, Neurosurgery & Psychiatry, S3*, 16-22.
2. Qureshi, A. I., Tuhrim, S., Broderick, J. P., *et al.,* (2001). Spontaneous intracerebral hemorrhage. *New England Journal of Medicine, 344*, 1450-1460.
3. Broderick, J., Connolly, S., Feldmann, E., *et al.,* (2007). Guidelines for the management of spontaneous intracerebral hemorrhage in adults: 2007 update: A guideline from the American Heart Association/American Stroke Association Stroke Council, High Blood Pressure Research Council, and the Quality of Care and Outcomes in Research Interdisciplinary Working Group. *Stroke, 38*, 2001-2023.
4. Bozzola, F., Gorelick, P. B., & Jensen, J. (1992). Epidemiology of intracranial hemorrhage. *Neuroimaging Clinics of North America, 2*, 1-14.
5. Sacco, R. L., Wolf, P. A., Bharucha, N. E., *et al.,* (1984). Subarachnoid and intracerebral hemorrhage: Natural history, prognosis, and precursive factors in the Framingham Study. *Neurology, 34*, 847-854.

6. Broderick, J. P., Brott, T. G., Duldner, J. E., *et al.,* (1993). Volume of intracerebral hemorrhage: A powerful and easy-to-use predictor of 30-day mortality. *Stroke, 24*, 987-993.
7. Fogelholm, R., Murros, K., Rissanen, A., *et al.,* (2005). Long-term survival after primary intracerebral haemorrhage: A retrospective population-based study. *Journal of Neurology, Neurosurgery & Psychiatry, 76*, 1534-1538.
8. Herbstein, D. J., & Schaumburg, H. H. (1974). Hypertensive intracerebral haematoma: An investigation of the initial haemorrhage and rebleeding using chromium Cr 51 labeled erythrocytes. *Archives of Neurology, 30*, 412-414.
9. Brott, T., Broderick, J., Kothari, R., *et al.,* (1997). Early haemorrhage growth in patients with intracerebral hemorrhage. *Stroke, 28*, 1-5.
10. Fujin, Y., Takeuchi, S., Sasaki, O., Minakawa, T., & Tanaka, R. (1998). Multivariate analysis of predictors of hematoma enlargement in spontaneous intracerebral hemorrhage. *Stroke, 29*, 1160-1166.
11. Fuji, Y., Tanaka, R., Takeuchi, S., Koike, T., Minakawa, T., & Sasaki, O. (1994). Hematoma enlargement in spontaneous intracerebral hemorrhage. *Neurosurgery, 80*, 51-57.
12. Hier, D. B., Davis, K. R., Richardson, E. P., Jr., *et al.,* (1977). Hypertensive putaminal hemorrhage. *Annals of Neurology, 1*, 152-159.
13. Robins, M., & Baum, H. M. (1981). The National Survey of Stroke: Incidence. *Stroke, 12*(2 Pt 2 Suppl 1), I45-I57.
14. Abu-Zeid, H. A., Choi, N. W., Maini, K. K., *et al.,* (1977). Relative role of factors associated with cerebral infarction and cerebral hemorrhage: A matched pair case-control study. *Stroke, 8*, 106-112.
15. Matsumoto, N., Whisnant, J. P., Kurland, L. T., *et al.,* (1973). Natural history of stroke in Rochester, Minnesota, 1955 through 1969: An extension of a previous study, 1945 through 1954. *Stroke, 4*, 20-29.
16. Ariesen, M. J., Claus, S. P., Rinkel, G. J., *et al.,* (2003). Risk factors for intracerebral hemorrhage in the general population: A systematic review. *Stroke, 34*, 2060-2065.
17. Mayer, S. A., & Rincon, F. (2005). Treatment of intracerebral haemorrhage. *Lancet Neurology, 4*, 662-672.
18. Matsukawa, H., *et al.,* (2012). Factors associated with lobar vs. non-lobar intracerebral hemorrhage. *Acta Neurologica Scandinavica, 126*, 116–121.
19. Wityk, R. J., & Caplan, L. R. (1992). Hypertensive intracerebral hemorrhage: Epidemiology and clinical pathology. *Neurosurgery Clinics of North America, 3*(3), 521-532.
20. Brott, T., Thalinger, K., & Hertzberg, V. (1986). Hypertension as a risk factor for spontaneous intracerebral hemorrhage. *Stroke, 17*, 1078-1083.
21. O'Donnell, M. J., Xavier, D., Liu, L., *et al.,* (2010). Risk factors for ischaemic and intracerebral haemorrhagic stroke in 22 countries (the INTERSTROKE study): A case-control study. *Lancet, 376*, 112-123.
22. Ariesen, M. J., *et al.,* (2003). Risk factors for intracerebral hemorrhage in the general population. *Stroke, 34*(8), 2060–2065.
23. Cho, D. Y., Chen, C. C., Lee, H. C., *et al.,* (2008). Glasgow Coma Scale and hematoma volume as criteria for treatment of putaminal and thalamic intracerebral hemorrhage. *Surgical Neurology, 70*, 628-633.
24. Thiex, R., Rohde, V., Rohde, I., *et al.,* (2004). Frame-based and frameless stereotactic hematoma puncture and subsequent fibrinolytic therapy for the treatment of spontaneous intracerebral hemorrhage. *Journal of Neurology, 251*(12), 1443–1450. https://doi.org/10.1007/s00415-004-0554-5
25. Morgan, T., Zuccarello, M., Narayan, R., *et al.,* (2008). Preliminary findings of the minimally invasive surgery plus rtPA for intracerebral hemorrhage evacuation (MISTIE) clinical trial. *Acta Neurochirurgica Supplement, 105*, 147-151.
26. Auer, L. M., Deinsberger, W., Niederkorn, K., *et al.,* (1989). Endoscopic surgery versus medical treatment for spontaneous intracerebral hematoma: A randomized study. *Journal of Neurosurgery, 70*, 530-535.
27. van Asch, C. J., Luitse, M. J., Rinkel, G. J., *et al.,* (2010). Incidence, case fatality, and functional outcome of intracerebral haemorrhage over time, according to age, sex, and ethnic origin: A systematic review and meta-analysis. *Lancet Neurology, 9*, 167–176.

28. Weimar, C., Weber, C., Wagner, M., *et al.,* (2003). Management patterns and health care use after intracerebral hemorrhage: A cost-of-illness study from a societal perspective in Germany. *Cerebrovascular Diseases, 15*, 29–36.
29. Mendelow, A. D., Gregson, B. A., Fernandes, H. M., *et al.,* (2005). Early surgery versus initial conservative treatment in patients with spontaneous supratentorial intracerebral haematomas in the International Surgical Trial in Intracerebral Haemorrhage (STICH): A randomized trial. *Lancet, 365*, 387-397.
30. Kaneko, T., Sawada, T., & Nnmi, T. (1983). Lower limit of blood pressure in treatment of acute hypertensive intracranial haemorrhage. *Cerebral Blood Flow and Metabolism, 351*, S51-S52.